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THE COTTON HOPPER, OR SO-CALLED "COTTON FLEA"[1]

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INTRODUCTION

At intervals during the past 25 years considerable local attention has been attracted to a peculiar disorder of the cotton plant in southern Texas. The more evident symptoms are the shedding of the very small squares and an abnormal type of growth involving often an excessive growth of the main stem. In extreme cases all varietal characteristics are obliterated (Pl. I, fig. 1). The shedding of the fruit frequently proceeds to such a point that practically none remains. For instance, in a field in Calhoun County in July, 1924, a group of 1,000 plants had a total of only 765 bolls. After a certain time the plants appear to recover to some extent and set fruit (Pl. I, fig. 2). Under ordinary conditions this is so late, however, that the fruit is all destroyed by the boll weevil.

The center of the disorder is a small group of counties on or near the coast of Texas including Calhoun, Refugio, Goliad, Victoria, and Jackson. In 1923 the same disorder appeared to a considerable extent in all counties along the lower Texas coast, and, to a less extent, in various localities throughout the central part of the State and even as far north as the Red River. Apparently 1923 was the first season in which the disorder occurred outside of the counties in the extreme southern portion of the State.

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[1] The field observations and experiments upon which this paper is based were made by A. C. Johnson and K. P. Ewing.

[2] Died Oct. 13, 1925. This manuscript was submitted for publication before Doctor Hunter's death and has been revised since by Dr. J. W. Folsom in the light of more recent developments.

In 1924 there was much less injury in Texas than in the preceding year, but it was almost as widespread. A striking feature, however, was the reporting for the first time of what seems to be the same or a very similar disorder in Georgia and South Carolina.

By local observers the shedding of the young squares is almost universally attributed to a small mirid, *Psallus seriatus* Reut. (fig. 1), which is known as the cotton hopper, although the beetle *Orthoperus glaber* Lec. is sometimes charged with the damage. That the mirid is the cause of the injury was the belief of the late J. D. Mitchell, of Victoria, Tex., who, in 1898, made a report to the then Division of Entomology. On this report L. O. Howard[3] based a brief statement which appeared in Bulletin 18 of the Bureau of Entomology. This note is practically the only one on the economic status of the insect in the literature.

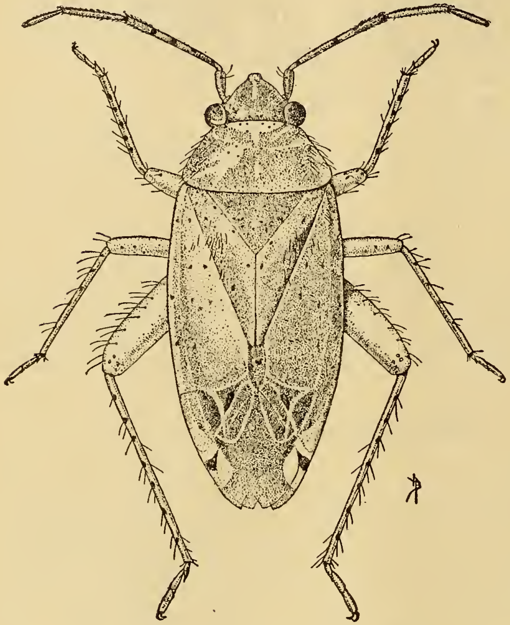

FIG. 1.—Adult stage of cotton hopper, *Psallus seriatus*. ×20

With the appearance of extensive injury in 1923, a preliminary investigation was begun. This was handicapped by reason of the fact that it did not start until July, although a number of interesting and suggestive points came to light. At the time any connection between the disorder of the cotton plants and the presence of the insect seemed doubtful, (1) because of the practically universal occurrence of the insect throughout the Cotton Belt and the extreme localization of the disorder, (2) because of the fact that in the majority of fields there was a general intermixture of normal and abnormal plants—a perfectly normal one frequently growing between two which were extremely abnormal—and (3) because the number of insects found in the field seemed to be entirely too small to produce the profound changes which took place in the growth of the plants. A further consideration was the fact that the destruction of the first-stage squares is frequently caused by the boll weevil and sometimes by the bollworm.

In an effort to determine whether there was some explanation other than insect attack, the work of 1923 was confined largely to observations on rainfall, soil, varieties, and tillage. Many fields

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[3] Howard, L. O. Some miscellaneous results of the work of the Division of Entomology. U. S. Dept. Agr., Div. Ent. Bul. (n. s.) 18, p. 101. 1898.

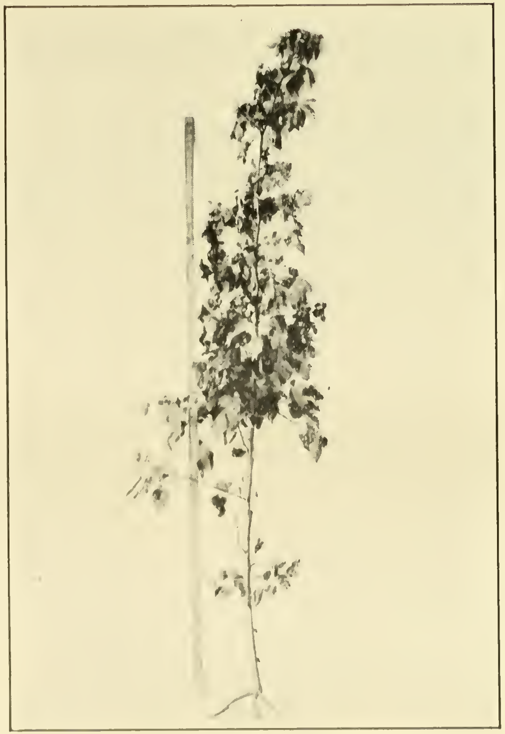

Fig. 1.—Lone Star Cotton Plant Showing Abnormality, Victoria, Tex., September 1, 1923. Stake at Side of Plant is 68 Inches High. The Curling and Perforation of the Leaves Were Caused by the Cotton Leafworm

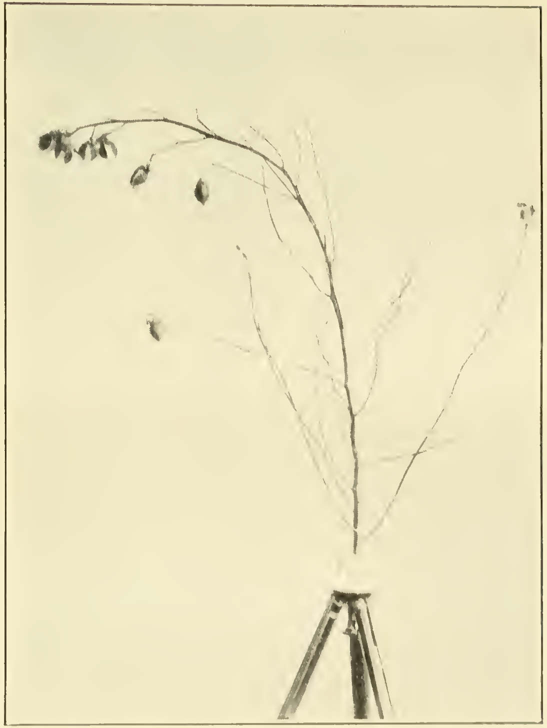

Fig. 2.—Mebane Cotton Plant Showing Recovery Late in Season, Smiths Point, Tex., September 25, 1924. Practically No Boll Weevil Present

in various parts of Texas were inspected. The general conclusions drawn were as follows:

(1) That the plants around the edges of a field are smaller, the yield is better, and in a general way they are more normal in structure.

(2) That plants in a depression of the land where drainage is poor are taller and show a more pronounced abnormality than the surrounding plants.

(3) That plants as a rule yield better and are more normal in structure where there is a decided slope to the land and where the drainage is good.

(4) That abnormal cotton occurs in different types of soil.

(5) That abnormal cotton occurs in fields surrounded by grassland and in some cases miles from other cotton.

(6) That the root development of normal and abnormal plants seems to be the same.

(7) That normal and abnormal plants will occur side by side in the same field.

As regards rainfall, no definite reading could be obtained. The precipitation at nine points in the seriously affected region for the months of April, May, and June was below the normal; but this was also the case at seven representative points in the central portion of the State where there was comparatively little injury. In the northeastern part of the State eight stations showed subnormal precipitation for April and May and an excess of 1.99 inches for June. These comparisons seemed clearly to negative any possibility that the distribution of the rainfall was an important contributing agency to the damage.

The failure to find a satisfactory explanation of the disorder in 1923 caused a special investigation to be undertaken by the Bureau of Entomology in Calhoun County, Tex., in 1924 with specific reference to the insect.

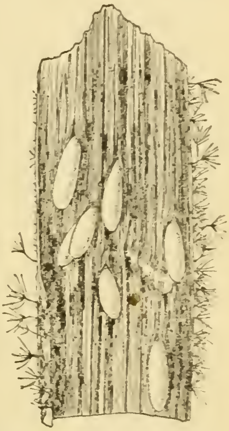

FIG. 2.—Eggs of cotton hopper in bark of Croton plant. ×13

Summarizing the results of the study of the life history of the insect in very brief form, it was first seen in the spring on the horsemint, *Monarda clinopodioides* A. Gray. Its first appearance was about the first of March in southern Texas. About the last of April when the horsemint had completed its growth and had begun to die, the hoppers migrated in large numbers to near-by cotton. During the first part of July the great majority migrated to Croton plants and by the end of that month very few could be found on the cotton. They continued to breed on Croton in large numbers until the end of the season.[4]

The eggs (fig. 2) were deposited principally on the main stem of the cotton plant and in an analagous position on the Croton, although they sometimes appeared on the leaves of that plant. The eggs could easily be found by removing the bark. Eight days was the average incubation period in a considerable series of observations. The nymph passed through four[5] stages, taking an average of 2¼ days to each stage. This brought the nymphs to maturity in 10 days and gave a period of from 16 to 18 days from oviposition to the maturity of the insect.

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[4] It is now known that the hopper breeds on Croton throughout the season.—Ed.

[5] Five stages are known to occur.

Feeding took place in the so-called bud of the cotton plant where young leaves, stems, and squares all seemed to be punctured indiscriminately.

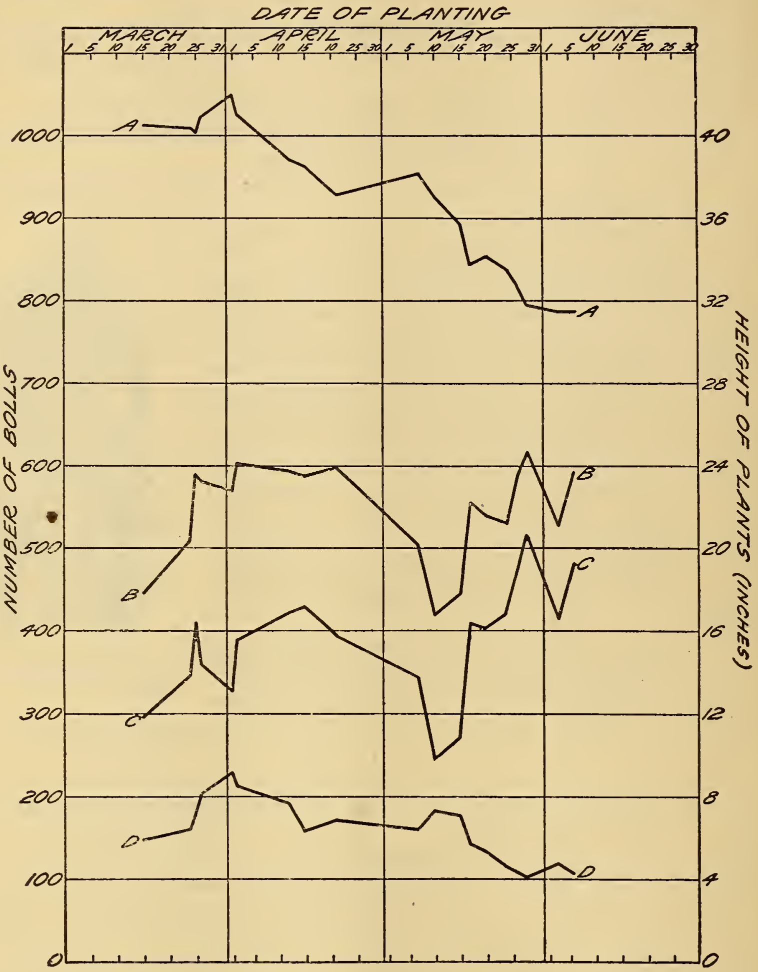

FIG. 3.—Field examinations, Port Lavaca, Tex., October 2–6, 1924. One hundred plants examined in each of 21 fields, in 4 groups of 25 plants each in each field. A–A, average plant height; B–B, average number of all bolls; C–C, average number of bottom and middle bolls; D–D, average number of top bolls

DISTRIBUTION

In the literature the cotton hopper is recorded from Maryland, District of Columbia, Florida, Utah, Colorado, New Mexico, Arizona, Texas, California, New Jersey, Georgia, and Kansas. In the present investigation it was found in the following additional States: Mississippi, Louisiana, South Carolina, and Oklahoma, as well as in the majority of the States in which it had been recorded previously. In the National Museum collection there are specimens from Alabama.

HOST PLANTS

Aside from cotton the hopper has been found in the adult and nymphal stages, indicating breeding, on the following plants: *Monarda clinopodioides* Gray; *Croton engelmannii* Ferg.; *C. engelmannii albinoides* Ferg.; *C. capitatus* Michx.; *C. texensis* (Klotsch) Muell.; *C. monanthogynus* Michx.; *Parthenium hysterophorus* L.; *Malvastrum americanum* (L.) Torr.

Apparently the last two plants are more or less accidental hosts. In the adult stage, the hopper has frequently been taken on a large number of plants; but such occurrences are probably all accidental.

RELATION BETWEEN DAMAGE AND TIME OF PLANTING

It was noticed that in Calhoun County, in 1924, as well as in other districts, there was a rather striking difference in the number of bolls on cotton planted at various dates and also considerable variation in the height of the plants. Between October 2 and October 6 a special study of this phase of the problem was made in Calhoun County. It consisted in determining the number of bolls in 21 fields planted at various dates from March 6 to June 6. In each field four groups of 25 plants each were examined. The number of bottom and middle bolls combined, the number of top bolls, and the total number of bolls were recorded, together with the height of the plants.

Table 1 and Figure 3 show the results of this study. It will be noted from the figure that there were two favorable periods for planting cotton in Calhoun County in 1924. On the basis of the total number of bolls formed early in October, the optimum periods of planting were from March 15 to May 1 and from May 15 to June 5. There was an intervening period from about May 1 to May 15 which resulted in plants of very low comparative production. It will also be noted that the total number of bolls was about the same for the early and late plantings, whereas the total number of bottom and middle bolls was somewhat greater for the later plantings. The number of top bolls alone showed a more or less regular decrease as the date of planting became later.

Another striking feature of Figure 3 is the practically regular decrease in the height of the plants resulting from early to late plantings. If this factor of plant height should be taken as a criterion of abnormality the conclusion would be inevitable that the disorder decreases in proportion as planting is deferred. However, such a conclusion is not warranted. The early plantings naturally had a longer period in which to grow and this alone would affect the stature of the plants.

It is clear that there was one definite period from about May 1 to May 15 which was decidedly unfavorable for planting cotton. This may have been caused by the migration of the hopper, which appeared in the fields early in April. Possibly the plants growing from the plantings between May 1 and May 15 were in a condition more susceptible to attack than the earlier plants which had attained some growth by the time of the migration.

Table 1.—*Total number of bolls set and their position with reference to dates of planting, Calhoun County, Tex., 1924*

[100 plants examined in each of 21 fields]

Date of planting	Average plant height	Bottom and middle bolls			Top bolls			Total bolls		
		Number	Period	Average	Number	Period	Average	Number	Period	Average
	Inches									
Mar. 6		204			144			348		
10		311			165			476		
15	40.5	376	Mar. 6–15	297	136	Mar. 6–15	148	512	Mar. 6–15	445
24	40.4	352	Mar. 10–24	346	189	Mar. 10–24	163	541	Mar. 10–24	510
25	40.2	505	Mar. 15–25	411	191	Mar. 15–25	172	696	Mar. 15–25	583
26	40.9	243	Mar. 15–26	369	295	Mar. 15–26	203	538	Mar. 15–26	572
Apr. 1	42.0	202	Mar. 24–Apr. 1	326	232	Mar. 24–Apr. 1	227	434	Mar. 24–Apr. 1	552
2	41.1	640	Mar 24–Apr. 2	388	164	Mar. 24–Apr. 2	214	804	Mar. 24–Apr. 2	603
12	38.9	509	Mar. 25–Apr. 12	420	80	Mar. 25–Apr. 12.	192	589	Mar. 26–Apr. 12.	591
15	38.6	357	Apr. 1–15	427	153	Apr. 1–15	157	510	Apr. 1–15	584
21	37.2	255	Apr. 1–21	393	225	Apr. 1–21	171	480	Apr. 1–21	596
May 7	38.2	265	Apr. 12–May 7	347	187	Apr. 12–May 7.	161	452	Apr. 12–May 7.	508
10	36.1	82	Apr. 15–May 10.	240	152	Apr. 15–May 10.	179	234	Apr. 15–May 10.	419
15	35.7	494	Apr. 21–May 15.	274	129	Apr. 21–May 15.	173	623	Apr. 21–May 15.	447
17	33.8	801	May 7–17	411	109	May 7–17	144	910	May 7–17	555
20	34.3	399	May 7–20	408	88	May 7–20	133	487	May 7–20	541
24	33.6	325	May 10–24	420	113	May 10–24	118	438	May 10–24	538
26	32.7	343	May 15–26	472	109	May 15–26	110	452	May 15–26	582
28	31.9	721	May 17–28	518	87	May 17–28	101	808	May 17–28	619
June 3	31.5	272	May 24–June 3	415	172	May 24–June 3.	120	444	May 24–June 3.	536
6	31.5	740	May 24–June 6	480	61	May 24–June 6.	108	801	May 24–June 6.	589

It would be entirely erroneous to conclude on the basis of the data now available that late plantings are advisable in regions where hopper attack is to be expected. The conditions in Calhoun County in 1924 were extremely abnormal as regards the boll weevil. On account of a protracted drought extending from the end of May throughout the growing period of cotton the weevil occurred in very small numbers. Even as late as October there were not enough present to produce any appreciable effect on the crop. Under normal conditions weevils would have appeared in considerable numbers throughout the season and the late-forming fruit would not have escaped them. Considering these facts, the only conclusion which is warranted from this study is that reasonably early planting is likely to result in a better crop than late planting.

It might be argued that the use of calcium arsenate would enable the farmer in a season of normal weevil occurrence to bring about a reduction in the number of weevils comparable to the reduction caused by climatic conditions during 1924. It is evident, however, that in certain counties in Texas it will be necessary to take some direct means to control the hopper, thus adding to the cost of production. If, in addition to such direct means, the farmer must apply poison for the boll weevil, his expenses will undoubtedly mount to a prohibitive figure.

An investigation to determine the best time for planting was made in Chambers County similar to that made in Calhoun County. Practically the same conditions were found; that is, early and late cotton produced comparatively large crops, whereas intermediate plantings produced very little. The same condition as regards the scarcity of the boll weevil occurred in Chambers County.

EXPERIMENTS TO DETERMINE INJURY TO COTTON BY THE HOPPER

The injury attributed to the hopper is characteristic. It consists in the blasting of the very small squares, usually not more than 2 to 4 millimeters in length. These squares turn brown or black, become dry, and fall from the plants.

A number of experiments were conducted in cages to determine whether the introduction of considerable numbers of hoppers resulted in the characteristic reaction of the young squares. The cages were 3 feet square and 4 feet high, covered in part with muslin and in part with celluloid. The cages all covered the same number of plants. The results are given in Table 2.

TABLE 2.—*Experiments in introducing cotton hoppers into cages with cotton; Calhoun County, Texas, 1924*

Cage	Number of hoppers introduced	Date introduced	Number of blasted squares found	Dates of finding blasted squares
1	397 nymphs and adults	June 25	51	June 25 to July 26.
Control			41	Do.
2	350 adults	June 28	56	Do.
Control			13	Do.
3	300 nymphs and adults	July 3	114	July 3 to Aug. 9.
Control			36	Do.
4	175 nymphs and adults	June 5–7	12	June 12.
Control			0	None found.
5	75 nymphs and adults	June 16–18	10	June 19.
Control			0	None found.

The total number of blasted squares found in all the cages in which hoppers were introduced was 243 as against a total of 90 in the control cages.

In practically all cases approximately equal numbers of nymphs and adults were introduced in the cages but in the case of experiment 2 only adults were introduced.

An important point about these experiments is that cages 1, 2, and 3 with the corresponding controls were placed over the plants after they had attained some growth; that is to say, hoppers in all probability came in contact with the cotton in the controls before the cages were placed. There is also more than a possibility that some of these control cages allowed the hoppers to make their way inside on account of the deterioration of the material as the season advanced. In experiments 4 and 5, however, with the corresponding controls, cages were placed over the plants before the migration of the insects into the field and there was no deterioration of the cages up to the time the examinations were made. It will be noticed that in these two cases no blasted squares whatever were found in the controls. Although the experiments need to be duplicated and extended, there is apparently a strong indication that it is the hopper which causes the blasting of the squares.

The fact that there was a practically uniform increase in the number of blasted squares in the first three cages, as compared with other controls, is also suggestive, especially when taken in conjunction with the results of the other experiments.

A supplementary experiment was conducted by placing cloth sacks over 10 cotton plants growing in the field. This was done on

June 25, at which time large numbers of hoppers were introduced with all of the plants except those which had also been covered but were used as controls. Examinations made up to July 23 showed 86 blasted squares in the sacks in which hoppers were introduced and 13 in the controls.

LOCAL EFFECTS OF FEEDING PUNCTURES

On the stems of horsemint and later on the stems of cotton plants it was observed that peculiar swellings occurred, their number being apparently in direct proportion to the number of hoppers present. These lesions were irregular in size and shape. In sacks inclosing portions of cotton plants where many hoppers were introduced the entire surface of the stems was covered with these excrescences. Numerous examinations failed to disclose any eggs within them. They appeared to be caused entirely by feeding punctures. Similar lesions were not found on the Croton plants, regardless of the number of hoppers occurring on them.[6]

Punctures of cotton stems with sterilized needles caused lesions apparently different from those occurring in the cages in which hoppers were introduced. Needle punctures left scars accompanied by some swelling in which the actual site of the puncture became depressed, resembling a crater. In the case of the lesions caused by the hopper, the entire surface was generally devoid of any craterlike depression.

DUSTING EXPERIMENTS

In the study of the damage caused to the cotton plant by the hopper a series of field experiments was conducted consisting of eight ½-acre plats which were treated with a dust containing nicotine in the form of sulphate on the supposition that it would destroy the hopper. Along with the plats treated with nicotine sulphate a similar series was treated with calcium arsenate, these with one exception being 1-acre plats. Calcium arsenate was employed on the theory that it would not affect the hopper but would eliminate the boll weevil. It had previously been determined that a certain amount of blasting of young squares is caused by the boll weevil and under some conditions by the bollworm.

The nicotine sulphate dust, which contained according to analysis 4 per cent of nicotine, was applied at 5-day intervals beginning May 20 and ending July 26. The application ranged from 6 to 20 pounds per acre.

The calcium arsenate plats were treated at 4-day intervals from May 20 to July 25. The quantity of poison used per acre application ranged from 2.5 to 12 pounds.

A preliminary examination before any of the applications were made showed the following average numbers of blasted squares per 50 plants on the entire series of plats: Controls, 127; nicotine sulphate, 110; calcium arsenate, 108. A summary of the dusting experiments is given in Table 3. Further results are shown in Table 4 which gives the total number of blasted squares found throughout the period of the experiment. Table 5 shows the average quantity of seed cotton per acre obtained at each picking on each of the series of plats; these results are further shown in Figure 4.

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[6] In 1925 such lesions were found abundantly on Croton.—Ed.

TABLE 3.—*Summary of dusting experiments against the cotton hopper, Calhoun County, Texas, 1924*

Plat	Blasted squares per 50 plants				Form counts per 30 plants				Plant height in inches				Yield of seed cotton per acre
	June 4–9	June 10–15	June 16–21	June 22–27	June 28	July 8	July 16	July 24	May 26	June 9	June 30	July 23	
													Lbs.
Control	56. 8	107. 2	152. 5	195. 5	151	175	378	326	7. 5	17. 1	26. 2	31. 7	519
Nicotine sulphate	46. 5	92. 8	118. 0	184. 6	195	191	401	394	8. 3	18. 2	27. 4	32. 3	573
Calcium arsenate	55. 2	110. 8	[1] 62. 0	184. 0	209	248	427	369	7. 6	15. 0	27. 3	29. 8	622

[1] In this case only two counts were made between June 16 and 21. In all other cases five to nine counts were made during the periods indicated.

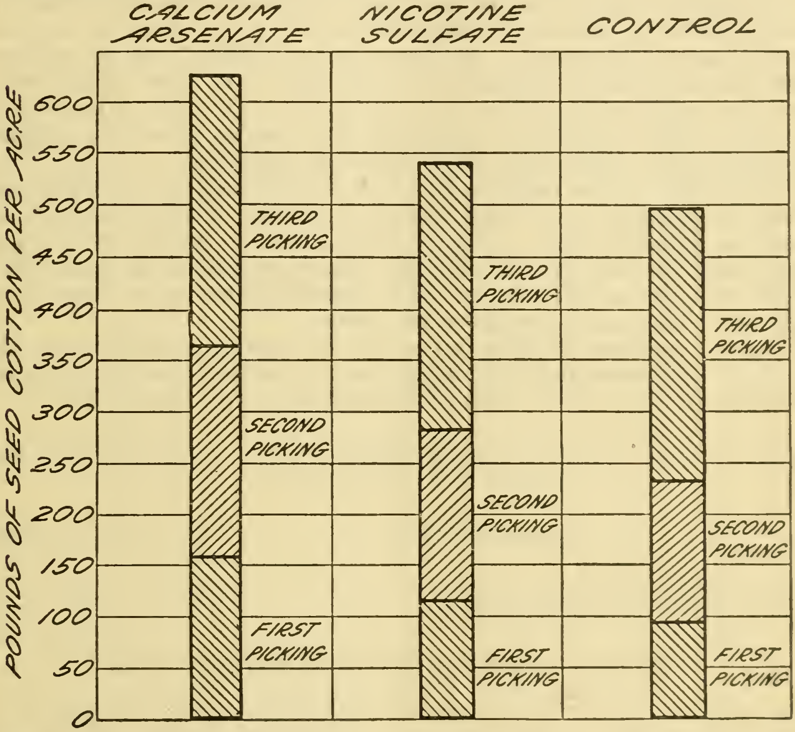

FIG. 4.—Yield of seed cotton per acre in experimental plats. The average dates of the first, second, and third pickings were August 7, August 18, and September 12, respectively

TABLE 4.—*Total number of blasted squares found in dusting experiments, June 4 to 27, 1924, Calhoun County, Tex.*

	Number of examinations	Number of squares per examination	Total number of blasted squares
Control	34	126. 5	4, 301
Nicotine sulphate	34	112. 0	3, 808
Calcium arsenate	16	105. 6	1, 690

TABLE 5.—*Yield of seed cotton per acre in pounds in plats used in dusting experiments*

	Control	Nicotine sulphate	Calcium arsenate
First picking	94	116	158
Second picking	141	165	206
Third picking	264	262	264
Total	499	543	628

It will be noted that the nicotine sulphate plats yielded about 9 per cent more than the controls and the calcium arsenate plats rather less than 25 per cent more. These increases are apparently attributable to the action of the insecticides, but how much was due to the effects on the hopper and how much to the effects on the boll weevil can not be stated. As shown later (Tables 7 and 8), calcium arsenate exerts some control on the hopper. It also undoubtedly operated against the boll weevil, although that insect was present in very small numbers. Therefore, the results from the calcium arsenate series represent a combination of influences.

To determine the possible effect of nicotine sulphate (2.8 per cent nicotine alkaloid) on the boll weevil, a number of observations were made on half-acre plats. Heavy applications to cotton in the field were made on July 18, 23, and 27. Daily records of the number of adult weevils on the dusted and control plants were kept until July 30. The results are given in Table 6.

These experiments show no effect of nicotine sulphate on the weevil. The increased yield in the nicotine sulphate series therefore seems to be due to the action of that substance on the hopper.

TABLE 6.—*Action of nicotine sulphate on the boll weevil in dusting experiments against the cotton hopper*

Number of weevils found	Control	Treated
Daily average before treatment	9	16
Daily average for 13-day period after treatment	6.2	10.3

FURTHER EXPERIMENTS WITH INSECTICIDES

In order to test the efficiency of various insecticides, a number of field experiments were conducted. A field was found which was originally planted to sorghum but had been abandoned. There were practically continuous rows of Croton plants in the middles. The hoppers were abundant on all of these. On August 8 a group of about a dozen Crotons was treated with each of several insecticides. Another group near by was designated as a control. One day after the applications were made and again five days thereafter, 50 blooming buds of the Croton plants were examined in each plat. The results are given in Table 7.

The Bordeaux mixture was a commercial concentrate used at the rate of 8 pounds to 50 gallons of water. The nicotine dust mixture contained 4 per cent of nicotine alkaloid. The sulphur was commercial flowers of sulphur. In all cases the insecticides were applied in excessive quantities, that is, considerably more was used than would normally be applied in practice.

On August 26 a greater number of materials was employed in a similar experiment. The Bordeaux was used at the rate of 8 pounds to 50 gallons of water, the nicotine (free, that is, not sulphate) at different nicotine alkaloid contents as indicated in the table. The nicotine sulphate dust whether used alone or with flowers of sulphur carried 4 per cent of nicotine alkaloid. The observations as to mortality were made on the first, fourth, and seventh days after the applications. The results are given in Table 8.

TABLE 7.—*Insecticide experiments against the cotton hopper on Croton plants in open; Calhoun County, Tex., 1924*

Insecticide	Forms alive after one day			Forms alive after five days		
	Nymphs	Adults	Total	Nymphs	Adults	Total
Control	111	37	148	136	35	171
Bordeaux mixture	191	21	212	122	29	151
Nicotine sulphate	43	33	76	124	20	144
Nicotine sulphate and sulphur, half and half	51	32	83	44	27	71
Sulphur	33	27	60	4	32	36

TABLE 8.—*Insecticide experiments against the cotton hopper on Croton plants in open; Calhoun County, Tex., 1924*

Insecticide	Forms alive after—											
	First day				Fourth day				Seventh day			
	Nymphs	Per cent	Adults	Per cent	Nymphs	Per cent	Adults	Per cent	Nymphs	Per cent	Adults	Per cent
Control	116	100	13	100	115	100	8	100	97	100	7	100
Bordeaux mixture	108	93	6	46	119	103	6	75	114	118	7	100
Lime	95	82	9	69	93	81	6	75	95	98	9	128
Miscible oil	84	72	7	54	74	64	8	100	69	71	7	100
Calcium arsenate	83	72	8	62	61	53	8	100	70	72	5	71
Nicotine, 2 per cent	68	59	4	31	78	68	4	50	78	80	5	71
Nicotine sulphate	66	57	8	62	86	75	7	88	91	94	7	100
Nicotine, 3 per cent	61	53	4	31	72	63	5	63	78	80	3	43
Nicotine, 4 per cent	55	47	3	23	68	59	4	50	77	79	4	57
Nicotine, 5 per cent	51	44	6	46	75	65	4	50	71	73	4	57
Nicotine sulphate and sulphur, half and half	36	31	7	54	34	30	7	88	56	58	6	86
Nicotine sulphate and sulphur, one-quarter and three-quarters	36	31	5	38	24	21	5	63	28	29	7	100
Sulphur	23	20	7	54	11	10	4	50	17	18	4	57

It will be noted that in both of these series of experiments (Tables 7 and 8) the greatest mortality was obtained by the application of flowers of sulphur. Its action began promptly and continued longer than was the case with other materials. It will also be seen that Bordeaux mixture showed little toxicity or repellent effect. Nicotine showed some effect but not nearly so much as sulphur.

Further experiments were conducted to determine with greater accuracy the action of various materials on the hoppers. In this series Croton plants growing in the field were given heavy treatments.

Immediately after such treatments 20 blooming buds were carefully removed from each plat and placed in ventilated glass cylinders. Observations were made on both nymphs and adults 4 hours and 24 hours after the applications. The results are shown in Table 9. It will be noted from the data here given that the superior effect of sulphur is again indicated. Bordeaux mixture and nicotine have the same relative position as in the field experiments and various mixtures of nicotine sulphate and sulphur were less effective than sulphur alone.

Table 9.—*Insecticide experiments against the cotton hopper on Croton plants treated in the field, buds being removed immediately to glass cylinders; Calhoun County, Tex., 1924*

Insecticide	After 4 hours								After 24 hours			
	Active		Inactive		Apparently dead		Total		Active		Dead	
	Nymphs	Adults	Nymphs	Adults	Nymphs	Adults	Nymphs	Adults	Nymphs	Adults	Nymphs	Adults
Control	106	5	0	0	3	2	109	7	80	4	29	2
Bordeaux mixture	113	1	6	1	1	1	120	3	77	0	43	3
Calcium arsenate	105	5	1	0	4	4	110	9	47	1	63	8
Nicotine sulphate, 4 per cent	26	5	32	7	14	1	72	13	49	5	23	8
Nicotine sulphate and sulphur, one-quarter and three-quarters	15	0	28	1	13	0	56	1	7	0	49	1
Nicotine sulphate and sulphur, half and half	2	0	24	3	29	1	55	4	1	1	54	3
Sulphur	0	0	17	0	47	6	64	6	2	0	62	6

Two final series of experiments on Croton plants infested with hoppers were conducted to determine the effect of diluting sulphur with kieselguhr or flour. The results are indicated in Tables 10 and 11. It will be noted that the addition of either of these two diluents greatly reduced the toxicity of the sulphur.

Table 10.—*Insecticide experiments against the cotton hopper with sulphur and kieselguhr on Croton plants in open; Calhoun County, Texas., 1924*

Insecticide	Nymphs alive after—					
	1 day		4 days		7 days	
	Number	Per cent	Number	Per cent	Number	Per cent
Control	121	100	70	100	47	100
Sulphur, 15 parts; kieselguhr, 85 parts	89	74	61	87	38	81
Sulphur, 25 parts; kieselguhr, 75 parts	92	76	57	81	32	68
Sulphur, 50 parts; kieselguhr, 50 parts	74	61	35	50	25	53

In the same connection a number of experiments were performed by spraying solutions of potassium sulphide on the Croton plants. Solutions at the following rates were used: 1 ounce to 1 gallon; 1 ounce to 2 gallons; 1 ounce to 4 gallons; 1 ounce to 6 gallons.

Three examinations made after these applications showed very little action against the hoppers.

TABLE 11.—*Insecticide experiments against the cotton hopper with sulphur and flour on Croton plants in open; Calhoun County, Tex., 1924*

Insecticide	Nymphs alive after—					
	1 day		4 days		7 days	
	Number	Per cent	Number	Per cent	Number	Per cent
Control	97	100	58	100	48	100
Sulphur, 15 parts; flour, 85 parts	65	67	34	59	32	67
Sulphur, 25 parts; flour, 75 parts	57	59	27	47	29	60
Sulphur, 50 parts; flour, 50 parts	43	44	21	36	22	46

THE EFFECT OF SULPHUR ON COTTON PLANTS

In none of the field experiments was any injury to cotton plants from applications of commercial flowers of sulphur detected. Later, with cotton planted in the greenhouse, as many as eight applications of sulphur to the amount of 500 pounds per acre were made at four-day intervals without any indication whatever of injury. This showing of tolerance to sulphur by the cotton plant has been confirmed by numerous observations made in connection with the boll-weevil work.

EXAMINATIONS FOR A CAUSATIVE ORGANISM

In the July, 1924, issue of the American Journal of Tropical Medicine, Strong[7] reports the finding of a flagellate in several plants of the genus Euphorbia of the same family as Croton. These flagellates are more or less pathogenic to the host plants. They are also found in a species of Coreidae, *Chariesterus cuspidatus* (Distant), and in a species of lizard. Strong's experiments indicate that the flagellate, as it occurs in the plant and also in the insect, is not pathogenic to vertebrates, but that when it has passed through the insect to the lizard it acquires pathogenic properties to the monkey.

Strong's experiments as well as other considerations indicated the importance of a search for a virus which might be transmitted by the cotton hopper. G. F. White, of the Bureau of Entomology, made numerous field examinations of the hopper and Croton and abnormal cotton plants. The results were altogether negative and it is practically certain that no large organism is involved in this disorder of cotton. It must be said, however, that these examinations were made in September, at which time a pathogenic organism might not be present. In order to complete this inquiry it will be necessary to make similar examinations in the spring when the hoppers are on the horsemint and when they first migrate to cotton.

GREENHOUSE EXPERIMENTS

In order, if possible, to hasten conclusions regarding the relation between the cotton hopper and the disorder of the plant, a number of plats were planted in a greenhouse at Houston, Tex., in September, 1924. Several hundred hoppers were introduced in two large cages each containing a dozen cotton plants. The insects were taken from Croton plants growing in the field since none could be found on cotton at that time. The hoppers paid very little attention to the cotton. The great majority of them died on the walls of the cages, although in a few instances feeding on the cotton plants was observed. At the present time (December 21, 1924) the plants in the cages have grown to a height of from 12 to 36 inches. They have begun to put on much fruit and appear to be perfectly normal except as they are affected by the light diffused through the glass of the greenhouse and by the cloth walls of the cages.

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[7] R. P. Strong. Investigations upon flagellate infections. *In* Amer. Jour. Trop. Med., vol. 4, pp. 345–372, illus. 1924.

A series of plants inoculated with fluid made from the crushed bodies of hoppers has also failed to show any abnormal reactions.[8] In order to determine whether the abnormality is transmitted through the seed, one plat of 20 plants was grown from seeds taken from extreme examples of disordered cotton plants growing in the fields. Up to the present time (December, 1924) the plants are normal, squaring profusely and showing no tendency to behave as did the plants producing the seed.

It is entirely too early to draw any definite conclusions from these experiments. Records will be continued until the plants mature, and there is a possibility that abnormal reactions will be found later.

The failure to obtain any abnormalities through inheritance is very suggestive. It tends to support the theory of insect transmission, but the experiment needs to be repeated before a final conclusion can be drawn.

SUMMARY

For a number of years a mysterious disorder of the cotton plant has occurred in certain localities in southern Texas. It is marked by the blasting of the very small squares, an abnormal type of growth, and often the excessive growth of the main stem. It is entirely unlike the disorders of cotton known as brachysm, tomosis, hybosis, stenosis, and cyrtosis. It also seems to be distinct from acromania, although showing more points of resemblance to that disorder.[9]

No connection whatever has been discovered between the disorder and soil, variety, or cultural or climatic conditions.

Practically all of the fields in certain large districts have been found to be affected by this disorder. Frequently it is so extreme that no cotton whatever is picked.

In the last few years the disorder appears to have spread to a number of localities in central and northern Texas, and in 1924 for the first time what appears to be the same thing occurred in South Carolina and Georgia.

The preliminary experiments reported in this circular are not conclusive in showing that the cotton hopper is the cause or the transmitting agent of the disorder, although they rather strongly suggest that the insect is the vector of a virus and two of the experiments in cages may constitute definite proof. The circumstantial evidence pointing to the hopper as a carrier is (1) the fact that the disorder appears to be similar to several disorders known to be transmitted by insects, (2) the seasonal history of the insect suggests it as a carrier of the infection, and (3) the disorder begins to appear as soon as the insects migrate to the cotton fields from another plant and subsides noticeably after the insects leave for other plants. In some cases, however, the recovery of the cotton plants is so complete that a very large top crop is produced, sometimes of sufficient weight to bend the abnormally tall plants to the ground. Moreover the hopper is by far the most common insect in the cotton fields at the time the disorder begins.

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[8] Later tests gave, however, lesions resembling those caused by the cotton hopper.—Ed.

[9] See the following papers:

Cook, O. F. A disorder of cotton plants in China: Club-leaf or cyrtosis. *In* Jour. Heredity, vol. 11, pp. 99–110, illus. 1920.

——— Malformations of cotton plants in Haiti. *In* Jour. Heredity, vol. 14, pp. 323–335, illus. 1923.

——— Acromania, or "crazy-top," a growth disorder of cotton. *In* Jour. Agr. Research, vol. 28, pp. 803–828, illus. 1924.

As against the possibility that the hopper transmits the disease, is the general occurrence of the insect throughout the Cotton Belt over a large part of which apparently the disorder has never appeared. The occurrence of disordered plants in the fields is sometimes decidedly irregular; whereas it might be expected that, if an insect transmitted the disorder, there would be a considerable degree of regularity in its appearance. With the preliminary work now done it should be possible in a very short time to make a definite determination of the rôle of the insect.

It is possible that there are additional spring host plants, but the first one found in southern Texas was the horsemint. About the last of April the insect migrated to cotton in abundance. Early in July there was another migration to several species of the genus Croton, on which it continued to breed until the end of the season.[10]

The feeding punctures of the insect on the stems of horsemint and cotton result in peculiar lesions.

By far the most effective material found for destroying the hopper was sulphur, which apparently can be applied in unlimited quantities to cotton without injury to the plants. Free nicotine and nicotine sulphate showed comparatively little effect. Bordeaux mixture, which either kills or repels the more or less related potato hopper, had practically no effect on the cotton hopper.

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[10] Now known to breed on Croton throughout the season.—Ed.

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